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SIXTEENTH ANNUAL REPORT OF THE POWER AFFILIATES PROGRAM

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FOREWORD

This report provides a summary of the activities of the Power Affiliates Program (PAP) in the Department of Electrical and Computer Engineering at the University of Illinois for the calendar year 1994. The information is intended to be a progress report to the affiliate companies listed below. The PAP is the foundation of the industrial liaison effort in the power and energy systems area. There are fifteen active affiliates associated with the PAP. They are:

Amoco Oil Company
Central Illinois Light Company
Central Illinois Public Service Company
City Water, Light and Power
Commonwealth Edison Company
Illinois Power Company
Iowa-Illinois Gas and Electric Company
Northern Indiana Public Service Company
Pacific Gas and Electric Company
PSI Energy
S&C Electric Company
Sargent & Lundy
Union Electric Company
W. W. Grainger, Inc.
Wisconsin Power and Light Company

1994 was an active year for the PAP and the highlights are covered in this report. We acknowledge the valuable support of the Affiliates and are most thankful to these companies for their continued support.

George Gross
Stan Helm
Phil Krein
Tom Overbye
M. A. Pai
Pete Sauer
Bob Turnbull

1. INTRODUCTION AND SUMMARY

The Power Affiliates Program was initiated in January 1979 as part of a major effort to strengthen the power and energy systems area. The original objectives were to:

- bring focus to the power and energy systems area
- provide financial assistance to students studying electric power engineering;
- increase university-industrial interaction at all levels of education and research in electric power engineering.

The program is described in considerable detail in Reference [1].

Throughout the past sixteen years, the Power Affiliates Program has maintained a stable base during times of rapid change. This base provided the seed money for research which led to additional funding by other sources. This base has also made it possible for students to be exposed to industrial problems and to participate in technical and professional meetings. With the cyclical nature of funding by government agencies, the Power Affiliates Program is a crucial source of support.

This annual report is organized as follows. A financial statement for the calendar year 1994 is given in Section 2. Section 3 describes how the power program fits into the departmental structure. There is no official degree or option associated with the power program, but there is a significant specialization in this area by a group of faculty members and courses. Section 4 gives a brief description of the courses specializing in electric power and gives the latest enrollment figures. Included in this section is a historical record of the number of graduates who have taken three or more of these courses. The record shows that student interest has been maintained and even broadened in recent years. Section 5 lists the activities of both the students and faculty members during the 1994 calendar year. Section 6 provides a brief summary of research projects which are funded by other sources. Section 7 gives information about the graduate students in the power area. In addition to personal data and interests, each student has written a brief abstract of his/her research work. Since 1987, the power faculty members have focused on enhancing the laboratory aspects of the curriculum and research efforts. The Grainger Foundation has funded three major laboratories ranging from electric machinery to power engineering software. These facilities are discussed in Section 8.

2. FINANCIAL STATEMENT

The following tabulation of income and expenditures for the calendar year 1994 was prepared from a detailed University statement as of December 31, 1994, Reference [2].

Income carried over from the calendar year 1993	$11,737
Total income during calendar year 1994	$68,061
Total available income during calendar year 1992	$79,798

Expenditure Category	Expenditure Amount
Personnel (Assistantships, wages)	$15,591
Materials/Supplies (Laboratory, library, office supplies)	$ 9,786
Transportation (Class trips, travel)	$ 6,536
Services (Publications, clerical, mailing, duplication, computer software, equipment maintenance)	$26,310
Equipment (Inventory equipment)	$ 1,751
Total	$59,974

Summary

Amount available during calendar year 1994	$79,798
Amount expended during calendar year 1994	-$59,974
Balance as of December 31, 1994	$19,824

3. THE POWER PROGRAM WITHIN THE DEPARTMENT

As of 1979, all entering electrical engineering students are required to complete 128 hours of course work for a B.S.E.E. degree. A detailed description of the undergraduate program as well as a suggested curriculum in Power are given in Reference [3]. All M.S.E.E. students are required to complete a minimum of 8 units (32 credit hours) and complete a graduate thesis. All Ph.D. students must qualify through a written examination and complete course and thesis requirements. A detailed description of the graduate program is given in Reference [4].

The Electrical and Computer Engineering Department is subdivided into eight distinct technical areas as follows:

Bioengineering and Acoustics

Circuits and Signal Processing

Communication and Control

Computational Science and Engineering

Computer Engineering

Electromagnetics, Optics and Remote Sensing

Microelectronics and Quantum Electronics

Power and Energy Systems

While the Department does not have official degree granting options in each of these areas, in practice, the eight areas serve as the appropriate grouping of the faculty activities and interest. In terms of size, the Power and Energy Systems area represents about 7% of the total active faculty and about 10% of the total student enrollment. The faculty committee in each area has the responsibility for administering courses and research in that area within the Department.

The Power and Energy Systems Area Committee and associated faculty for the 1994 - 1995 academic year together with their general interests are:

G. Gross	(Power System Economics, Planning and Operations; Public Utility Regulatory Policy; Utility Restructuring)
M. S. Helm, Emeritus	(Power System Analysis)
P. T. Krein	(Power Electronics, Machines, Electrostatics)
T. J. Overbye	(Dynamics, Stability and Operations of Power Systems)
M. A. Pai	(Dynamics, Stability and Computational Methods in Power Systems)
P. W. Sauer	(Modeling and Simulation of Machines and Power Systems)
R. J. Turnbull	(Energy and Conversion Technology, Sensors)

A detailed summary of each faculty member's research activities is given in Reference [5].

Two of the primary responsibilities of the Power and Energy Systems Area Committee are to update and staff the courses assigned to the Power and Energy Systems Area. In 1994-1995 those courses were:

ECE270	Introduction to Circuit Analysis (Joint responsibility)
ECE330	Electromechanics
ECE333	Electric Machinery
ECE336	Advanced Electromechanical Energy Conversion
ECE364	Power Electronics
ECE369	Power Electronics Laboratory
ECE371GG	Techniques for Engineering Decisions
ECE371EV	Advanced Electric Vehicles (Solar Powered Vehicle)
ECE371SUN	Solar Powered Vehicle Challenge
ECE376	Power System Analysis I
ECE378	Power System Analysis II
ECE452	Computer Methods in Electric Network Analysis (Joint responsibility)
ECE468	Modeling and Control of Electromechanical Systems
ECE473	Operation and Control of Power Systems
ECE476	Dynamics and Stability of Power Systems
ECE490	Power and Energy Systems Area Seminar
ECE497GG	Electric Resources Planning

The three-hundred level courses are advanced undergraduate or beginning graduate courses, while the four-hundred level courses are graduate. Of these courses, ECE336, ECE468, ECE473, and ECE497GG were not taught during the 1994-1995 academic year. The Power and Energy Systems Area Committee continuously evaluates each course outline for possible revision in future semesters. A brief description of each of these courses, together with the enrollment of the past year, are included in the next section. In addition, Power Area faculty are active in ECE345, Design Projects. This is the capstone design course for our seniors.

4. COURSES AND ENROLLMENT

As one of eight major areas in Electrical and Computer Engineering, the Power and Energy Systems Area is responsible for a considerable number of courses. The current courses assigned to the power area are described briefly below. The total annual enrollment for the 1994-1995 academic year is also given for each course.

ECE270 Introduction to Circuit Analysis (Primary responsibility for this course is assigned to the circuits and signal processing area committee.)

ECE270 is the first course that all electrical engineering students must take after their math, physics and computer science requirements. The course introduces elementary signal waveforms, electrical component models, and basic principles of circuit analysis including d-c, transient and sinusoidal steady-state analyses. The topical outline includes resistance, inductance, capacitance and source elements, Kirchhoff's laws, node and mesh equations, matrix methods, Thevenin and Norton equivalents, controlled sources, operational amplifiers, transient switching d-c analysis, impedance and transfer functions for steady state, frequency response, Bode plots, filters, mutual inductance, transformers and basic three-phase circuits. The required text was: Electric Circuits, 4th Edition by J. W. Nilsson. The total enrollment for academic year 1994-1995 was 732.

ECE330 Electromechanics

ECE330 is an introductory course in electromechanics, presenting both the electric and magnetic quasi-static fields for analysis of energy conversion devices. The origin of forces and torques, together with the full mechanical dynamics of Newton's Second Law (NSL), are discussed. The concepts of flux linkage, energy, co-energy and the resulting induced voltages are presented for their inclusion in Kirchhoff's Voltage Law (KVL). Conservation of power and energy is emphasized in energy balance analysis. An introduction to rotating machines is included with illustrative examples. Particular emphasis is given to the interaction between the electrical system (KVL) and the mechanical system (NSL). The supplemental text was Electromechanical Dynamics, Part I: Discrete Systems by H. H. Woodson and J. R. Melcher, with required notes by M. A. Pai. The total enrollment for the academic year 1994-1995 was 146.

ECE333 Electric Machinery

This four-hour course contains a laboratory one credit hour component which is an elective in a list of 14 from which students select two. The fifteen experiments typically include power measurement, power factor correction, transformer characteristics, three-phase transformer connections, induction motor tests, induction motor torque-speed characteristics, synchronous machine tests, synchronous machine power characteristics, digital simulation of machine dynamics, motor control, and a written plus oral project presentation on power and energy system topics. The required text was Basic Electric Machines by Del Toro. The total enrollment for the academic year 1994-1995 was 33.

ECE336 Advanced Electromechanical Energy Conversion

This three-hour course contains advanced theory and analysis of rotating and linear machines and drives. It includes power electronic drives for dc and ac motors. The analysis uses d-q transformations and related techniques. Emphasis is placed on the time scale modeling of electromechanical devices and on their function in drives. Class notes are used. The course was not offered during the academic year 1994-1995.

ECE364 Power Electronics

This three-hour course is a comprehensive treatment of switching power conversion systems and the devices used to build them. Concepts of switch control are developed from general switching functions. Phase control, pulse width modulation, and phase modulation are studied for applications in all types of converters. Converter topologies are introduced along with design concepts for power filters and interfaces. Devices such as diodes, thyristors, bipolar transistors, field effect transistors, capacitors, and magnetic components are examined in the context of high-power switching applications. The required text was Principles of Power Electronics by Kassakian, Schlecht and Verghese. The enrollment for academic year 1994-1995 was 48. The course has been produced on videotape.

ECE369 Power Electronics Laboratory

This two-hour course is a laboratory study of circuits and devices used for switching power converters, solid-state motor drives, and power controllers, including dc-dc, ac-dc, and dc-ac converters and applications. It includes high-power measurements for silicon-controlled

rectifiers, diodes, capacitors, power transistors and magnetic components. The course is designed to accompany ECE364. A lab manual by P. Krein is available for the course. The total enrollment for the academic year 1994-1995 was 24.

ECE371GG Techniques for Engineering Decisions

This course is aimed at providing the skills and techniques for solving some typical problems faced in making engineering decisions in industry and government. The focus is on analytic schemes and systematic methodologies for making decisions with explicit consideration of the economic aspects. The course topics include time value of money, selection of alternatives, scheduling and inventory analysis and decision making under uncertainty. Several test cases will be covered. The required texts were: Modern Engineering Economy, 1993 edition, by D. Young and Operations Research, Principles and Practice, 1992 edition, by A. Ravindran, D. Phillips, and S. Solberg. The total enrollment for the academic year 1994-1995 was 24.

ECE371EV/ME393DRW Advanced Electric Vehicles

This project-oriented course began with the complete design, construction, and testing of a working hybrid electric vehicle which combines an electric traction system with a fueled auxiliary power unit. The course was not offered during the 1994-1995 academic year.

ECE371EV Advanced Electric Vehicles (Solar Powered Vehicle)

During 1994, a new project to initiate the design of a solar-powered vehicle was the focus of the course. This is a project oriented course which involves the design and construction of a solar power car. On the electrical side there is an array of solar cells, a d-c to d-c connected to charge batteries, and an electrical drive system including an induction motor. The enrollment for the 1994-1995 academic year was 21.

ECE376 Power System Analysis I

This three-hour course is the first of two courses on power system analysis. Topics included are transmission line parameter calculations, equivalent circuits, network analysis, load flow, fault analysis, symmetrical components, unsymmetrical fault analysis, and introduction to economic dispatch and relaying. The course is designed to give the basic fundamentals of power system analysis and provide preparation for the follow-on course. The required text in the academic

year 1994-1995 was Power System Analysis by A. Bergen. This course was also offered to off-campus working engineers by videotape. The enrollment was 30 on campus.

ECE378 Power System Analysis II

This three-hour course is the second of two courses on power system analysis. Topics included are economic operation of power systems, optimal load flow concepts, automatic generation control, state estimation, classical transient stability, modeling for dynamic and transient stability, and d-c transmission. The enrollment was 16.

Graduate Courses:

ECE452 Computer Methods in Electric Circuit Analysis (Primary responsibility for this course is assigned to the circuits and signal processing area committee.)

ECE452 is a graduate course designed for both electric power and electronic students. The course presents the fundamental computer algorithms utilized to analyze scale circuits. Applications in both electronic circuit design and power system analysis are given. The following topics are presented: Network topology and circuit equations, branch constraints and problem formulation, solution of sparse linear algebraic equations, solution of nonlinear algebraic equations, power and electronic system applications, solution of piecewise linear algebraic equations, explicit and implicit numerical integration methods, transient analysis of power and electronic circuits, sensitivity analysis and decomposition. No text was required, classnotes were used. The total enrollment for the academic year 1994-1995 was 35.

ECE468 Advanced Modeling and Control of Electromechanical Systems

This course addresses issues of electrical drives in a modern control and circuit framework. Dynamic models of electric machines are presented. There is special emphasis on field-oriented control methods for ac motors. Power electronic systems for high-performance drives are studied. Nonlinear system methods such as periodic transformations, averaging, geometric control, and feedback linearization are presented. Special topics covered include electrostatic micromachines and permanent magnet machines. Internal notes by P. Krein are available for the course. The course was not offered during the academic year 1994-1995. The course has been produced on video tape.

ECE473 Operation and Control of Power Systems

The course includes energy control center functions, power system operating states, supervisory control and data acquisition, state estimation, on-line load flow, security assessment, economic dispatch, automatic generation control, optimal power flow, security constrained economic dispatch, multistage rescheduling and equivalents. The course was not offered during the 1994-1995 academic year.

ECE476 Dynamics and Stability of Power Systems

The course includes the dynamic representation of interconnected power systems - electrical plus mechanical, linearized dynamic models of multimachine systems, methods of coherency identification, order reduction by singular perturbation, time scale decomposition and aggregation techniques, dynamic equivalents, direct methods of stability analysis and power system stabilizer design. The current course text is a set of notes prepared by P. W. Sauer and M. A. Pai. This course is available on video tape. The enrollment for the academic year 1994-1995 was 8.

ECE490 Power and Energy Systems Area Seminar

This course is a graduate seminar on advanced topics of current interest. Both faculty and students participate by presenting either current research results or topics of interest in journal publications. Guest speakers from industry and other universities are also scheduled periodically throughout the semester. The enrollment for 1994-1995 was 18.

ECE497GG Electric Resources Planning

This course provides coverage of the basic techniques in electric utility resource planning including methodologies for reliability evaluation and assessment, production costing, marginal costing, supply-side and demand-side planning and integrated resource planning. Throughout the course, probabilistic approaches are emphasized. In place of a text, notes specifically prepared by George Gross are used. The course is being given once every two years and was not offered during the 1994-1995 academic year.

NUMBER OF ELECTRIC POWER AND ENERGY SYSTEM AREA GRADUATES FOR RECENT YEARS

1950-1970 Annual Average Power Area Graduates

B.S.E.E. - 25
M.S.E.E. - 3

1970-1980 Annual Average Power Area Graduates

B.S.E.E. - 44
M.S.E.E. - 7

1980-1985 Annual Average Power Area Graduates

B.S.E.E. - 30
M.S.E.E. - 5
Ph.D. - 2

1985-1992 Annual Average Power Area Graduates

B.S.E.E. - 35
M.S.E.E. - 6
Ph.D. - 2

1992-1993 Power Area Graduates

B.S.E.E. - 37
M.S.E.E. - 7
Ph.D. - 2

1993-1994 Power Area Graduates

B.S.E.E. - 51
M.S.E.E. - 6
Ph.D. - 1

1994-1995 Power Area Graduates

B.S.E.E. - 35
M.S.E.E. - 8
Ph.D. - 2

5. ACTIVITIES

The faculty and students in the Power and Energy Systems Area participated in a considerable number of special activities during calendar year 1994. The major events are listed below:

- IEEE Power Engineering Society Winter Meeting
  - Tom Overbye presented a paper on Voltage Collapse and attended committee meetings.
  - Pete Sauer chaired the working group on Dynamic Security Assessment.
  - George Gross chaired the Computer and Analytical Methods Subcommittee meeting.
  - Stan Helm participated in committee meetings.

- Sargent and Lundy Faculty Engineering Conference
  - Stan Helm attended.

- ECE333 and ECE378 student class trip to the Newton Generating Station and the CIPS Energy Control Center

- Engineering Open House
  - ECE333 students presented machinery demonstrations.

- American Power Conference
  - Stan Helm coordinated the UI participation in the sponsored student, sponsored faculty program.
  - 11 students and faculty sponsored by Central Illinois Public Service Co., Commonwealth Edison Co., Illinois Power Co., Sargent & Lundy, Union Electric, Wisconsin Power and Light.
  - George Gross, Tom Overbye and Pete Sauer attended.
  - George Gross organized and chaired a session on opening up the transmission system to third-party users.

- IEEE Power Engineering Society Transmission and Distribution Conference
  - 5 undergraduates (Doug Brown, Jonathan DeMaster, Darren Hite, Brad Johnson and Kim Parson) received third place in a student design competition. Tom Overbye was the faculty advisor.

- IEEE Power Engineering Society Summer Meeting
  - Pete Sauer chaired the working group on Dynamic Security Assessment.
  - George Gross chaired the Computer and Analytic Methods Subcommittee meeting.
  - Stan Helm attended committee meetings.
  - Tom Overbye attended committee meetings.

- IEEE Industry Applications Society Annual Meeting
  - Bob Turnbull and Phil Krein attended committee meetings.

- The hybrid electric vehicle team took part in the National 1994 Hybrid Electric Vehicle Challenge in Southfield, Michigan. The team took first place in Engineering Design, second place overall, and received several special awards.

- North American Power Symposium (NAPS)
  - Pete Sauer presented a keynote address on the history of NAPS.
  - M. A. Pai presented a paper co-authored with D. Morris.
  - Ray Klump presented a paper on power system voltage stability.

- College of Engineering Advisory Board Meeting
  - The Advanced Electric Vehicle students presented their projects.

- Phil Krein gave several presentations to university, civic, and industry groups about the hybrid electric car.

- National Institute of Standards
  - George Gross was invited to be and participated in a member of the National Research Council Panel for the Assessment of the Electrical and Electronic Laboratory of the National Institute for Standards and Technology.

- Tom Overbye and Pete Sauer presented papers at the 3rd Bulk Power System Voltage Phenomena Conference in Davos, Switzerland.

- M. A. Pai conducted the following two-day workshops in India in 1994.
  - "Voltage and Small Signal Stability in Power Systems," Indian Institute of Technology, Bombay, July 1994.
  - "Voltage Stability in Power Systems," Central Power Research Institute, Bangalore, India, August 1994.

- Wheeling and Dealing: Electric Transmission in the 1990's Conference, Oak Brook, IL

  - George Gross gave a presentation on transmission costing issues.

- Hosted the following guest speakers:

  - Dr. Nelson Martins, CEPEL, Rio de Janeiro, Brazil, "Current Activities in Power System Dynamics and Control"
  - Dr. Nelson Martins, CEPEL, Rio de Janeiro, Brazil, "Demo on Pacdyn, The Small Signal Electromechanical and Voltage Stability of Cepel"
  - Michehl R. Gent, NERC, "It's Time to Play by the Rules"
  - Prof. V. Vittal, National Science Foundation, "The Power System Program Area at NSF"
  - Dr. Narain G. Hingorani, Electric Power Research Institute, "Power Electronics in Electric Power Systems"
  - Dr. Atef S. Morched, Ontario Hydro, Toronto, Ontario, Canada, "Introduction to the Electromagnetic Transient Program (EMTP)"
  - Dr. J. H. Chow, Rensselaer Polytechnic Institute, "Design of Robust Controllers for Damping Power System Oscillations"

- Prof. Costas Vournas, National Technical University, Athens, Greece, "Voltage Stability and Collapse in Multiple Time Scales"

- Participated in multi-university seminar exchange over the internet for the following seminars:
  - Prof. Dennis Ray, University of Wisconsin, "Power System Simulations: Insight or Mystery?"
  - Dr. Ray Zimmerman, Cornell University, "Comprehensive Distribution Power Flow: Modeling, Formulation, Solution Algorithms and Analysis"
  - Dr. Felix Wu, University of California, Berkeley, "What's Wrong with Hogan's Contract Network/Poolco?"

- G. Gross was convener and organizer of the IGPA Regulatory Roundtable focusing on issues of interest in the restructuring of the electricity business; attendees included regulatory commissioners, high level utility executives, and academics from several states.

- National Science Foundation (NSF) Symposium on Electric Power System Infrastructure
  - G. Gross and P. W. Sauer attended the NSF Symposium organized at Washington University at Pullman, Washington.
  - G. Gross presented keynote address to the NSF Symposium on Electric Power System Infrastructure, Pullman, Washington.
  - P. W. Sauer chaired a session and co-authored the final assessment report.

- Edison Electric Institute Power System Planning and Operations School
  - G. Gross is co-director of this school given at UIUC and U.C., Berkeley, twice a year.

6. RESEARCH FUNDED BY OTHER SOURCES

The Power Affiliates Program is a source of seed money which enables the faculty to obtain support from major funding agencies. The following pages summarize the projects which have been made possible through this growth.

High-Performance Power Supplies

P. T. Krein, P. Midya, U. Ekambaram

Sorensen Co.

Operational techniques required in high-performance switching power supplies are being explored. Control methods based on geometric and optimal concepts are under study for applications in supplies with fast dynamic response. The methods represent a large-signal approach to design and control. Synchronous rectifiers and related switching techniques are being studied for applications in low-voltage systems. The new techniques are expected to lead to performance improvements while simplifying the design process.

Advanced Electric Vehicle Program

P. T. Krein, R. A. White, T. Roethemeyer, B. Masterson, R. Reppa, et al.

University of Illinois; U. S. Department of Energy; Ford Motor Co.; Illinois Corn Growers Assn.; Illinois Power Co.; Magnetek, Inc.; Commonwealth Edison Co.; Central Illinois Light Co.; other industrial sponsors

(In conjunction with the Department of Mechanical and Industrial Engineering)

A hybrid electric vehicle combines an electric traction system with a fueled auxiliary power unit. Such a vehicle can perform like a gasoline car, with substantial emission reductions, at reasonable cost. Design tradeoffs differ from those in purely electric vehicles. This project involves the complete design, construction, and testing of a practical hybrid electric vehicle. An advanced power electronic traction drive system is a key electrical element in the system. More than 250 undergraduate students and several additional faculty consultants were involved. For 1994-95, a team of about 100 students is preparing a solar powered car for competition.

Simulation Methods for Switching Power Networks

P. T. Krein, Dan Beck

Teltrend, Inc.

Switching power conversion networks pose severe problems for conventional circuit simulators. The discontinuous action, the wide disparities in time scales, and the sensitivity to semiconductor device models offer challenges. This project compares several power electronic simulation methods. Test circuits for use as benchmarks will be identified. Performance predictions will be compared with actual operating results to identify the advantages and disadvantages of the various approaches.

Advanced Nonlinear Induction Motor Control

P. T. Krein, J. Locker, B. Truax

National Science Foundation Fellowship; University of Illinois

Field orientation is a widely used control method for ac induction motors. Recent results in nonlinear control theory, including feedback linearization and integrator backstepping, offer possible alternatives for ac servo systems. Observer techniques allow high performance without expensive sensors. This project examines the operating performance of new motor control alternatives. Methods are studied analytically, through detailed simulation, and experimentally. A digital signal processing motor drive system is available for tests.

Optimal Control Approaches to Power Electronic Systems

P. T. Krein, P. Midya

National Science Foundation Fellowship

Power electronic circuits are inherently nonlinear and can be controlled only through operation of switches. In past practice, linearization and small-signal approximations are often applied to such circuits for control design purposes. Optimal control methods offer a way to decide how "best" to control such circuits. However, conventional optimal methods do not apply to nonlinearities of the type found in power electronics. This project develops approaches, based on standard optimization, which can be used for switching control. The results can be used to provide good large-signal performance as well as excellent small-signal operation. Geometric methods can be used to demonstrate that the alternatives give approximate optimal operation of a power electronic circuit.

Convergence Characteristics of Newton-Raphson Power Flow for Stressed Power Systems with Significant Device Limits

T. J. Overbye*, R. P. Klump

National Science Foundation, ECS 92-09570

The Newton-Raphson power flow is used as a major tool for analysis of the nonlinear power system loading equations, though usually with moderately loaded systems without the need to consider a large number of device limitations. However, future systems will be more stressed, and as advanced electronic control devices proliferate there will be a vast increase in the number of device limits that must be considered. This research is investigating the convergence properties of the Newton-Raphson power flow for such cases, with the goal of developing improved solution methods.

Computation of Realizable Methods to Restore Power Flow Solvability

T. J. Overbye*

National Science Foundation, ECS 92-09570; Power Affiliates Program

As power systems become more heavily loaded, system operation will be increasingly constrained by contingent cases for which the power flow equations have no real solution. The goals of this project are to develop a measure to quantify the unsolvability of such cases and to determine the optimal controls to restore the case to solvability. A Euclidean norm is used in parameter space to measure the degree of unsolvability. The sensitivity of this measure to different system controls is then used to determine the best controls to restore the case to solvability. Both the static and dynamics aspects of the problem are considered.

Use of Computer Simulation for Effective Visualization of Current and Future Power System Operations

T. J. Overbye,* P. W. Sauer, C. M. Marzinzik, G. Gross

Edison Electric Institute; Power Affiliates Program

The electric-utility industry is entering one of the most turbulent periods of change in its entire history. The current pressures of regulation and competition, combined with the rapid influx of new information, communication, and control technologies, make it difficult to accurately predict the eventual structure of the industry. However, given the complexities of the power system, it is important that the industry undertake a managed redesign. To accomplish this managed redesign, it is important to be able to communicate clearly the complex issues involved in power

system operation and to identify the essential operating requirements needed to maintain security under any restructuring alternative. In this project we are examining the use of computer visualization/simulation to achieve these goals.

Structural Stability in Power Systems

M. A. Pai, P. W. Sauer, B. Lesieutre, R. Ranjan, S. Fernandes

Electric Power Research Institute, RP 8010-21

In this research we looked at the effect of parameter variations on the stability of power systems. Structural stability refers to the property of the system when the qualitative behavior is not significantly altered when a parameter varies. When the behavior alters significantly, the structural stability boundary is reached. In the literature this is also referred to as the bifurcation boundary. Applications of this theory include voltage collapse and robust design of power system stabilizers. We have investigated the effect of nonlinear voltage-dependent loads as well as induction motor loads on voltage collapse. Also the effect of uncertainties in load modeling on robust stability has been investigated using Kharitonov-Barmish testing functions. An important result regarding the limits on load indices for existence of load flow solutions was obtained. The project was completed with the final report available as TR-103870-R1, November 1994.

Parallel Processing in Dynamic Simulation of Large-Scale Power Systems

M. A. Pai, A. Kulkarni

National Science Foundation, ECS 91-19428

Parallel processing algorithms for dynamic response calculations of large power systems with detailed models are being developed. The work is based on solving the differential-algebraic system of equations of the power system using the simultaneous-implicit method. Instead of parallelizing the L-U method for solving the resulting system of linear equations at each time step using Newton's method, we use the General Minimal Residual (GMRES) method which belongs to the family of conjugate gradient methods. This is an iterative solver and is easily parallelizable. Preconditioners using ILU(s) technique are successful in providing fast simulation. The convex C3 machine with 8 processors is used to demonstrate the technique. The simulation using the research code agrees with the EPRI-ETMSP program and is currently being extended to the 50-machine 145-bus IEEE system with a detailed two-axis model and IEEE Type I exciter.

Sensitivity and Adaptive Control in Power Systems

M. A. Pai, M. Laufenberg

National Science Foundation, ECS 91-19428

In this research, we are investigating the use of trajectory sensitivities of the nonlinear dynamic power system to study the proximity of a stressed system to synchronous instability. The sensitivities are computed both with respect to critical parameters and initial conditions for a post-fault system. The idea is to obtain a non-transient energy function based technique to rank contingencies in DSA. Further work on detailed models will include adaptive control of PSS by adjusting critical parameters.

Hopf Bifurcation in Power Systems

M. A. Pai, D. Morris

National Science Foundation, ECS 91-19428

In this research, we developed the enhancement to a Matlab-based research grade program for Small Signal Stability Analysis (SSSA). This package is based on analytical linearization and gives exactly the same eigenvalue results as the EPRI-SSSP program. It uses the power balance equations and is flexible to include dynamic devices as well as to compute transient responses. We investigated low frequency oscillations (Hopf bifurcation) in power systems using this software on a two-area system.

Multirate Integration Methods in Power Systems

M. A. Pai, T. Courtney, Katherine Blossfield

National Science Foundation ECS 91-19428 REU

In this research, we are investigating the simulation of a power system having different time frames of dynamic phenomena using multirate integration techniques. The end objective is faster simulation. Instead of a purely numerical analysis approach, we do a time-scale decomposition of the system into fast and slow subsystems. We have obtained good results initially on a single machine system where the stator transients are considered fast and the rest of the dynamics are slow. This is an on-going project involving undergraduates in the department.

Small Signal Stability of Electric Power Systems

M. A. Pai, University of Illinois, D. P. Sen Gupta and K. R. Padiyar, Indian Institute of Science, Bangalore, India

National Science Foundation, INT-9302565

This is a three-year collaborative project under the Indo-U.S. Cooperative Program in Science. In addition to the academic exchange of ideas through mutual visits, work has begun on a research monograph covering the topics of eigenvalue analysis, Hopf bifurcation, adaptive PSS, SSR and SSP with FACTS devices.

Robust Stability in Power Systems

M. A. Pai (Jointly with A. N. Michel, University of Notre Dame), C. D. Vournas

National Science Foundation, ECS93-19352

In this project, robust stability of power systems under parameter as well as varying operating conditions will be investigated using interval matrix techniques. Also we plan to obtain bounds on parameter variations of a nonlinear dynamic system such that the equilibrium point is still stable.

Load Modeling Concepts

P. W. Sauer and S. Fernandez

National Science Foundation, ECS 93-18695

This project is examining the basic structure of power system load modeling to determine the generic forms which capture critical phenomena. Time-scale analysis is being used to understand reduced-order models of aggregate loads and to formulate various levels of detail. Of particular interest is the effect that load models have on the nonlinear dynamic behavior of power systems. Initial results have shown that there is a fundamental difference between the effects of several large machines versus those of many small machines.

7. STUDENT PROJECTS

This section of the report contains information on the graduate students whose major research efforts were supervised by faculty in the Power and Energy Systems area. While not all of these students received financial aid from the Power Affiliates Program in terms of Research Assistantships, they were all associated with the program through the active involvement of their respective advisors. Those students supported by the Power Affiliates Program received maximum one-half time Research Assistantships for 11 months. The results of each student's work will be made available to all affiliate companies in the form of technical reports. The following students were associated with the Power and Energy Systems Area and their work is described in the following pages:

Cullum, David (M.S.)
Das, Paritosh (M.S.)
Ekambaram, Uma (M.S.)
Fernandes, Stephen (Ph.D.)
Finlay, David (M.S.)
Klump, Ray (M.S.)
Kulkarni, Ajit (Ph.D.)
Laufenberg, Mark (Ph.D.)
Locker, Jonathan (Ph.D.)
Marzinzik, Caroline (M.S.)
Midya, Pallab (Ph.D.)
Morris, David (M.S.)
Mwase, Naomi (M.S.)
Reppa, Robert (M.S.)
Roethemeyer, Tim (M.S.)
Shimony, Anat (M.S.)
Splater, Scott (M.S.)
Tombuloglu, Burak (M.S.)
Truax, Byron (M.S.)
Wang, Shaojun (Ph.D.)
Weinstock, Rob (M.S.)

David Cullum

Date of Birth: December 1, 1969

Place of Birth: Peekskill, New York

B.S.: January 1992, University of Illinois

M.S.: May 1994, University of Illinois

Professional Interests: Power system protection, voltage instability and collapse.

Use of Energy Methods to Approximate Maximum Power System Loadability

David Cullum with advisor T. J. Overbye

Supported by the Power Affiliates Program and the National Science Foundation

ABSTRACT

Energy methods have been shown to be useful measures for approximating the vulnerability of power systems to voltage instability and collapse. An energy-based measure has been developed for system models with constant real power and voltage-dependent reactive power load models. This energy measure can be related to the area enclosed by a Q-Ln(V) curve, or that of a P-α curve. This relationship shows promise because it provides an interpretation of the energy measure for an operational environment by giving information about the maximum loadability of the system. This energy-based voltage security measure relationship, however, is an approximation for the case with transfer conductances. The objective of this research was to develop a better approximation for the transfer conductance case which will not degrade the ease of computation nor destroy the relationships with the Q-Ln(V) curve and P-α curves.

Paritosh Das

Date of Birth: December 1, 1966

Place of Birth: Khulna, Bangladesh

B.S.: August 1992, Bangladesh University

M.S.: In progress

Professional Interests: Power system economics, control systems.

Power Pool for Competitive Electricity Market

Paritosh Das with advisor George Gross

Supported by the Grainger Foundation and the Power Affiliates Program

ABSTRACT

Joint organization among electric utility companies in the form of power pools is primarily directed at the introduction of operating economics through coordinated interchange of power on a regional basis. In the restructured utility, a power pool operating in an integrated system is deemed to play a key role by providing an environment for easy interactions between generators, transmission and distribution network, and the consumers to attain economic efficiency. This work focuses on determining a pool model that would be sound from both technical and economic viewpoints and evaluating the performance of the pool in a competitive power market.

Uma Ekambaram

Date of Birth:	November 24, 1969
Place of Birth:	Madras, India
B.S.:	May 1991, College of Engineering Guindy, Madras, India
M.S.:	February 1994, University of Illinois
Current status:	Doctoral Student, Circuits Area, UIUC.

Distributed Low Voltage Power Converters

U. Ekambaram with advisor P. T. Krein

Supported by the Power Affiliates Program and Sorensen Company

ABSTRACT

Low-voltage power distribution in automobiles, computers, telecommunications, and other applications is an issue of growing importance. With voltage levels of 12 V, 5 V, 3.3 V, or even less, distribution at the nominal voltage becomes difficult, and the wiring is heavy. For these systems, power can be distributed at a higher bus level, such as 48 V or 300 V, then converted to low voltage locally at each load. This project examined the special characteristics and problems in distributed dc-dc systems. The various distributed system arrangements were studied and compared based on typical applications. Solutions to some of the major special problems were proposed and tested. Analysis and experiments were conducted for a prototype 48 V to 2 V conversion system. One example of a special problem is bus overload response. Power converters act as constant power loads, and will draw excessive current if the distribution bus sags during an overload. A priority shutdown system was designed and tested to mitigate this problem. If a sag occurs, loads set for "low priority" will shut down to alleviate the overload while maintaining system operation. The project has successfully developed new design ideas for distributed dc-dc conversion systems.

Stephen Fernandes

Date of Birth:	September 3, 1967
Place of Birth:	Rourkela, India
B.S.:	May 1989, Institute of Technology Varanasi, India
M.S.:	July 1992, Oregon State University
Ph.D.:	In progress (Mr. Fernandes is currently on leave of absence)
Professional Interests:	Control systems, power systems.

Structural Stability and Bifurcation Analysis in Power Systems

Stephen Fernandes with advisor P. W. Sauer

Supported by the National Science Foundation

ABSTRACT

This project is examining the dynamic behavior of power systems at critical loading levels. The research is investigating the modeling requirements to detect loadability limits that arise from dynamic instabilities. The initial work is focusing on load models. While dynamic load models need to reflect the wide use of induction motors, the system model cannot simply use a single induction motor dynamic model. General dynamic load models are being investigated to see which ones properly reflect the characteristics of many induction motors.

David Finlay

Date of Birth: January 21, 1971

Place of Birth: Dublin, Ireland

B.S.: July 1993, University College, Dublin, Ireland

M.S.: In progress

Professional Interest: Economics of power systems.

Generator Bidding Strategies in the England and Wales Power Pool

David Finlay with advisor George Gross

Supported by the Grainger Foundation

ABSTRACT

There are mounting commercial and environmental pressures on regulators to introduce the perceived beneficial effects of competitive forces into the structure of the electric power industry in the United States. The privatization of the England and Wales electricity supply industry has played a large part in unleashing these pressures for restructuring. The experience in the U.K. has shown that competition brings with it a whole new set of problems that until now have not concerned power system engineers. Not the least of these problems is the development of bidding strategies to take advantage of the sealed bid auction for the right to serve load.

In this work, we have developed a very general Competitive Power Pool framework which includes the structure of the Power Pool in England and Wales. A comprehensive mathematical model of the operation of this competitive structure has been completed. Taking explicit account of the unique constraints that generators of electrical power operate under, the optimal bidding strategy problem has been formulated and solved for the case of a perfectly competitive market. This result provides a useful tool for operations and system planners. Procedures for determining the profitability of units, estimating profit volatility and evaluating the return on investments in plant efficiency have been developed. Numerical simulations that illustrate the theoretical results and provide insights into the way in which units with different characteristics function in this competitive environment have been performed.

Ray Klump

Date of Birth: March 31, 1971

Place of Birth: Berwyn, Illinois

B.S.: May 1993, University of Illinois

M.S.: In progress

Professional Interests: Power systems.

Study and Enhancement of Newton-Raphson Power Flow Convergence Properties

Ray Klump with advisor T. J. Overbye

Supported by the National Science Foundation

ABSTRACT

The Newton-Raphson formulation of the power flow has been a standard power systems analysis tool for many years. For most of that time, interest has focused primarily on finding a single power flow solution starting from an initial guess, which is normally close to the expected solution. However, as systems have become more heavily loaded, transient stability and voltage stability have become growing areas of concern. Assessing these types of stability often requires finding power flow solutions at which the power system typically would not operate; these are the so-called low voltage solutions. Currently, finding these low voltage solutions poses a significant challenge and requires a substantial amount of guesswork because the convergence properties of the Newton-Raphson load flow equations are not well-understood. The purpose of this investigation is to explore these convergence properties so as to make the Newton-Raphson power flow more deft at finding alternative solutions.

Ajit Kulkarni

Date of Birth: April 10, 1967

Place of Birth: Chicago, Illinois

B.S.: May 1988, Arizona State University

M.S.: January 1990, University of Illinois

Ph.D.: In progress

Professional Interests: Development of and applications of computer methods to large scale power system analysis, including application of supercomputers. Interested in a career in the electric utility industry.

Parallel Processing in Dynamic Simulation of Large Scale Power Systems

A. Kulkarni with advisor M. A. Pai

Supported by the National Science Foundation and the Grainger Foundation

ABSTRACT

The focus of this research is on the use of parallel processing in power system dynamic simulation. Efficient use of computer hardware of the supercomputer, such as Cray machines, and research into better numerical algorithms which are parallelizable are being investigated. The linear multistep predictor corrector method was successfully used on the Cray-2 machine with four processors both in the autotasked mode and the macro-tasked mode. A classical model for the machine was used. A system with up to 50 machines has been tested, and for the numerical integration portion, a speedup of 3.79 compared to a theoretical speed of 4 was obtained. Current research involves extending the technique to systems containing both differential and algebraic equations. Parallelizing the simultaneous implicit method using conjugate gradient style methods with suitable preconditioners has been done on the Cray Y-MP, Convex, and IBM RS6000 for the 10-machine 39-bus system with detailed two-axis representation for each machine. Currently the work is focussed on the General Minimal Residual (GMRES) method and applying it to the IEEE test system of 50 machines. The GMRES method is suitable for the parallel computation in solving $Ax = b$ where A is sparse and nonsymmetric.

Mark Laufenberg

Date of Birth: March 27, 1969

Place of Birth: Dodgeville, WI

B.S.: May 1992, University of Illinois

M.S.: August 1993, University of Illinois

Ph.D.: In progress

Professional Interests: Nonlinear systems, adaptive control.

Dynamic Sensitivity Analysis and Control of Power Systems

Mark Laufenberg with advisor M. A. Pai

Supported by the National Science Foundation, Power Affiliates Program
and the Grainger Foundation

ABSTRACT

Sensitivity theory as applied to a nonlinear dynamic system has been studied extensively in the automatic control literature both with respect to parameter variations and changes in initial conditions. Trajectory sensitivities, in particular, can be used in power systems to estimate system stability for a given contingency. They can provide an indication of the proximity of the state of the system to the stability boundary at the instant of fault clearing. Initial results are encouraging. These estimates can then be ranked to filter the most critical contingencies. It may be possible to design automatic control systems to either correct for critical contingencies or operate the system more economically by adaptive control of relevant parameters.

Jonathan Locker

Date of Birth:	September 14, 1970
Place of Birth:	Peoria, Illinois
B.S.:	May 1992, Washington University
M.S.:	January 1995, University of Illinois
Ph.D.:	In progress
Professional Interests:	Control systems for industrial applications.

An Experimental Comparison of Induction Motor Control Methods

Jonathan Locker with advisor P. T. Krein

Supported by the National Science Foundation and the Grainger Foundation

ABSTRACT

Many induction motor controls currently use simple scalar methods, such as constant volts per hertz or constant magnetizing current, to achieve good steady-state performance. Field-oriented control is also used for a variety of applications. Recent advances in control theory have produced complicated nonlinear control algorithms that show promise for many industrial applications. In this project, we implement these methods on a test bench to compare and contrast their actual operating performance.

Caroline Marzinzik

Date of Birth: February 3, 1972

Place of Birth: Springfield, Illinois

B.S.: May 1994, University of Illinois

M.S.: In progress

Professional Interests: Power systems.

Development of a User-Friendly Power System Simulation

Caroline M. Marzinzik with advisor T. J. Overbye

Supported by the Grainger Foundation

ABSTRACT

As power systems become increasingly complex, there is a continual challenge to provide improved tools for power system education. Traditionally, this training has been provided primarily to student engineers, system operators, and practicing engineers. However, a worldwide movement towards more open system access (evidenced in the United States by the Energy Policy Act of 1992) has created an unprecedented need to expand this pool. Now, as never before, there is a need for personnel without an extensive technical background to have at least a basic understanding of power system operation to ensure that the interactions between business decisions and technical constraints are considered and understood. This research project has developed a Windows-based simulation program to help meet this challenge. The simulation allows users to dynamically interact with a simulated power system through various windows, including a one-line diagram. The main emphases of the program are basic power flow in a network, how system controls (such as generator MW/voltage setpoint, LTC transformers and power transactions) affect power flow, and area control concepts such as ACE, AGC, and economic dispatch.

Pallab Midya

Date of Birth:	January 31, 1967
Place of Birth:	Bhilai, India
B.S.:	Indian Institute of Technology, Kharagpur
M.S.:	May 1990, Syracuse University
Ph.D.:	April 1995, University of Illinois
Current Status:	Motorola, Schaumburg, IL

Nonlinear Control and Operation of DC to DC Switching Power Converters

P. Midya with advisor P. T. Krein

Supported by the Power Affiliates Program and Sorensen Company

ABSTRACT

Conventional control of switching power conversion is based on a linear model of the system, which limits its scope and performance. This thesis addresses a family of control and operation issues that arise from the nonlinear nature of the switching power conversion. The focus is on dc to dc power converters with a small number of states. Nonlinear noise analysis of conventional feedback has been performed to evaluate this important aspect of converter performance. Alternative schemes are developed that reduce noise susceptibility, reduce effects of source and load disturbances, and improve system operation. A nonlinear control scheme, called sensorless current mode (SCM) control, has been developed that emulates current mode control without current sensing. SCM has very significant advantages in dynamic range and noise susceptibility. Optimal control approaches to switching power conversion have been explored. Optimization of a nonmonotonic tuning problem has also been explored. A generalized tuning scheme has been developed and implemented for practical converters with excellent results.

David Morris

Date of Birth: December 13, 1970

Place of Birth: Chicago, Illinois

B.S.: December 1992, University of Illinois

M.S.: May 1994, University of Illinois

Professional Interests: Power systems, control systems.

Analysis of Bifurcations in Power Systems

David Morris with advisor M. A. Pai

Supported by the National Science Foundation and the Grainger Foundation

ABSTRACT

Static bifurcation in power systems which occurs for stressed cases is associated with physical concepts such as voltage collapse and maximum loadability. When dynamic models of power systems are included in the analysis, we have the Hopf bifurcation phenomenon resulting in oscillatory phenomena which is generally unstable. In this research, we investigated this and studied the impact of other dynamic devices, such as the PSS and turbine governor effects on Hopf bifurcation. Enhancements to a MATLAB software for small signal analysis (SSA) was made and the results agree with the EPRI-SSSP package. A realistic two-area system was used in the studies. Inclusion of LTC, FACTS, SVC and other dynamic devices such as induction machines is proposed as future enhancements to this package.

Naomi Mwase

Date of Birth: June 3, 1966

Place of Birth: Ndola, Zambia

B.S.: January 1988, Polytechnic of the SouthBank, London

M.S.: In progress

Professional Interests:Power systems, control systems.

Optimization Based Power Flow Studies

Naomi Mswae with George Gross

Supported by the Grainger Fellowship Foundation

ABSTRACT

Powerworld is a power simulation program currently under development. Using Powerworld as a basis, optimization-based power flows will be used to investigate optimal utilization of transmission systems. Optimal enhancement of transmission systems and pricing strategies for transmission providers will be considered also.

Robert Reppa

Date of Birth: August 13, 1968

Place of Birth: Lansing, Illinois

B.S.: May 1990, United States Military Academy at West Point

M.S.: In progress

Professional Interests: Switching power converters, alternative energy.

Optimization of a Maximum Power Point Tracker

Robert Reppa with advisor R. J. Turnbull

Supported by the Department of Energy and the Power Affiliates Program

ABSTRACT

The amount of power derived from a solar module depends roughly on incident radiation and temperature. The module terminal characteristics will operate where the load line of the device to which it is connected intersects the module I-V curve. This intersection rarely matches the maximum power point of the module; hence, full use is not made of the available solar energy. A switching power converter which tracks the maximum power point of a solar module has been developed. This device has been optimized for efficiency and applied to the University of Illinois "Sunchief" solar car as a vehicle power management system.

Tim Roethemeyer

Date of Birth:	July 26, 1964
Place of Birth:	Nashville, Illinois
B.S.:	August 1993, University of Illinois
M.S.:	January 1995
Current Status:	General Motors Corp., Electric Vehicle Program, Troy, MI.

Traction Motor Control of Electric Vehicles

T. Roethemeyer with advisor P. T. Krein

Supported by the Hybrid Electric Vehicle Program

ABSTRACT

(Mr. Roethemeyer served as Electrical Student Team Leader for the College of Engineering's Hybrid Electric Vehicle Program)

This research deals with the complex control that accompanies an induction motor-based traction system for an electric vehicle. With recent advances in power electronics, variable speed induction motor drives are readily available. Only a vector-control drive can be used for the torque control which is required for a transportation vehicle. Primarily, dc bus current control may be used with an ordinary speed control drive to produce a quasi-torque controller without the need for accurate attributes of the motor (as are necessary for proper operation of vector control drives). The motor can also be directly coupled to a manual transmission in which proper motor control during the shifting process provides quick, accurate clutchless shifting.

Anat C. Shimony

Date of Birth: November 17, 1966

Place of Birth: Haifa, Israel

B.S.: August 1991, Technion, I.I.T.

M.S.: In progress

Professional Interests: Bioelectromagnetics, computational techniques in electromagnetic fields and waves, power and control systems.

Development of Three-Dimensional Software Simulations of the Magnetic Fields in a Residence and Surroundings

Anat C. Shimony with advisors R. L. Magin, P. T. Krein and R. J. Turnbull

Supported by the Power Affiliates Program and the Grainger Foundation

ABSTRACT

The goal of this project is to develop a software simulation for the three-dimensional visualization of 60 Hz magnetic fields in a typical residence and its surroundings. The simulation and display software will provide a dynamic tool for the realistic analysis of magnetic field distributions. For example, the simulation could be used to explore field intensities in the vicinity of house appliances.

Scott Splater

Date of Birth: November 24, 1971

Place of Birth: St. Louis, Missouri

B.S.: May 1993, University of Illinois

M.S.: In progress

Professional Interests: Alternative energy, control systems, electric vehicles.

Testing and Performance of a Practical Hybrid Electric Vehicle

Scott Splater with advisor P. T. Krein

Supported by the Power Affiliate Program and Teaching Assistantship

ABSTRACT

The University of Illinois has produced a fully operational series Hybrid Electric Vehicle (HEV) through the conversion of a production automobile, making it one of the first complete hybrid conversions. While it retains all of the passenger and trunk space of the original vehicle and performs comparably to many production vehicles, its true series hybrid nature makes significantly higher fuel mileage and lower emissions possible. It has won two national awards for Best Engineering Design and has been the top-performing series conversion vehicle at both the 1993 and 1994 Hybrid Electric Vehicle Challenge competitions; now it serves as a test bed for evaluation of models and analysis of design attributes for practical hybrid cars. Main topics of exploration include the identification and analysis of critical design factors and performance attributes relating to energy management in a hybrid vehicle, analysis of lead-acid battery maintenance issues and strategies in this setting, and determination and evaluation of detailed component models for all elements of a series hybrid car. Through simulation and actual road and lab driving tests, basic and advanced models of such elements and the larger systems can be validated.

Burak Tombuloglu

Date of Birth: November 17, 1971

Place of Birth: Milwaukee, Wisconsin

B.S.: May 1993, University of Illinois

M.S.: In progress

Professional Interests: Telecommunications systems, signal processing.

Electric Utilities as Telecommunications Providers for the National Information Infrastructure

Burak Tombuloglu with advisor George Gross

Supported by the Power Affiliates Program and Grainger Foundation

ABSTRACT

This research is a multidisciplinary look at what role an electric utility can play in the proposed NII or "Information Superhighway." Electric utilities are uniquely situated as players in the NII by virtue of the existing rights of way they possess as well as the extensive telecommunications networks they maintain. The goal of this work is to develop a strategic plan for an electric utility to enter into this arena and cooperate with other carriers to provide a unified local telecommunications network. Economic and regulatory issues are being explored as well as the technical details of building such a network.

Byron Truax

Date of Birth:	January 30, 1953
Place of Birth:	Columbus, GA
B.S.:	June 1989, Southern Illinois University
M.S.:	March 1995
Current Status:	Cummins Engine, Columbus, Indiana.

A Generic Digital Testbed for Induction Motor Controllers, with Programmable Load

Byron Truax with advisor P. T. Krein

Supported by the University of Illinois ECE Dept.

ABSTRACT

This project builds on previous work by Scott A. Ellerthorpe to provide a testbed for implementation and evaluation of induction motor control strategies. The testbed includes a microcontroller (programmable in a high-level language [C]), sensors for measurement of shaft position, speed, and stator voltage and current, a switching power inverter, and an RS-232 user interface. A programmable load simulator using a dc machine has been added to the system. The objectives are to develop, demonstrate, and compare methods for precise dynamic control of induction motors, under a variety of realistic load conditions. The load simulator provides real-time torque to emulate almost any physical loading condition.

Shaojun Wang

Date of Birth: January 4, 1967

Place of Birth: Hebei, P.R. China

B.S.: July 1988, Tsinghua University

M.S.: July 1992, Tsinghua University

Ph.D.: In progress

Professional Interests: Electric resources planning and restructuring.

Multi-Area Production Costing

S. Wang with advisor G. Gross

Supported by the Power Affiliates Program and Grainger Foundation

ABSTRACT

The rapidly changing environment in which electric utilities operate today makes the consideration of multi-area power systems a pressing need in strategic and resource planning. A critical issue for multi-area studies is to have the multi-area analogue of single area production costing. The multi-area production cost simulation model must correctly take into account the impacts of transmission constraints as well as interconnection operation policies. The objective of our work is to build a general model to simulate the operation of multi-area power systems under various operation policies, which range from totally centralized pool-wide dispatch to independent operation dispatch. Major applications of our research include interchange contract evaluation, geographically differentiated marginal costing, pricing of services and strategic and resource planning.

Rob Weinstock

Date of Birth: February 2, 1965

Place of Birth: Des Plaines, Illinois

B.S.: August 1989, University of Illinois

M.S.: In progress

Current Status: Student in M.B.A. program at UIUC.

Optimal Sizing and Selection of Hybrid Electric Vehicle Components

Rob Weinstock with advisor P. T. Krein

Supported by the Hybrid Electric Vehicle Program

ABSTRACT

A hybrid electric vehicle (HEV) combines electric traction with fuel energy storage. Proper execution of a successful HEV design for transportation applications requires optimal sizing of key mechanical, electrical, and power electronic components. An active program for HEV development is now in progress. The basic objective of an HEV design is to match the performance of a standard automobile while drastically reducing emissions. Constraints imposed while optimizing critical component selection are: vehicle range, acceleration, maximum speed, total emissions, cost, recharging, and driveability. An HEV designed and built at the University of Illinois has made good use of the tradeoffs. This vehicle has the look, feel, and performance of a stock automobile while providing emission reductions of 80-90% in extended driving, and up to 99% in short-range commuting.

8. LABORATORY FACILITIES

The Power Area has assembled some of the nation's finest facilities for experimental and computer-based research and teaching. Both undergraduate and graduate students can take advantage of these facilities. These laboratories have generated wide interest. They contribute significantly to growth in the Area.

The Grainger Power Engineering Software Laboratory was established in 1988 with funds from the Grainger Endowment. It is located near the office areas on the third floor of Everitt Laboratory. The Laboratory has three IBM RS6000s and three DEC engineering workstations. Four stations have full color graphics. In addition, there are four advanced personal computers. A laser printer serves the computers. All stations are connected to the campus network, which, in turn, provides access to major international networks via Internet.

A major objective of the laboratory is to develop an extensive library of commercial software and large-scale data bases for power area applications. Software is based on the Unix operating system and on MS-DOS. Some of the commercial software packages currently in use include:

Mathematica (an advanced symbolic mathematics package)
PECO (Philadelphia Electric power system software collection)
ETMSP (EPRI Extended Transient Midterm Stability Program)
ATP (Alternate electromagnetics Transients Program)
MatrixX (system analysis software)
SYMNON (system analysis and design software)
IPFLOW (Interactive Power Flow)
SSSP (Small Signal Stability Analysis)
INSITE (Interactive Nonlinear Systems Investigative Toolkit for Everyone)
MatLab

The software library is being expanded continually.

The Grainger Electrical Machinery Laboratory is located on the ground floor of Everitt Laboratory. This facility is primarily for undergraduate teaching, and is used for ECE 333, ECE 369, and the Advanced Electric Vehicle Program. Ten self-contained machinery workstations are available. Each has an integral horsepower machine set, digital watt meters, oscilloscope, optical tachometer, torque sensor, and electronic support instruments. Transformers, resistor units, capacitors, SCR circuits, and power FET units are provided in support of the full range of experiments in all aspects of power. The facility has a dedicated 225 KVA three-phase supply and a 50 kw d-c rectifier bank.

The laboratory has generated a great deal of interest among students and other universities.

Student participation continues to grow. The equipment allows experimental work to be more complete without sacrifice of hands-on experience for students.

The Advanced Power Applications Laboratory is located adjacent to the Grainger Electrical Machinery Laboratory. This laboratory serves as a general research facility for all hardware aspects of power electronics, machines, and power systems. The lab shares motor test sets with the Machinery Lab. Additional equipment is available for the study of harmonic effects, high-performance switching converters, and digitally controlled drives. This laboratory has extensive computer facilities, which communicate with the Grainger Power Engineering Software Laboratory through the building network. Current projects include harmonic effects in uninterruptible power systems, high-performance distributed power supplies, advanced ac motor controllers, and electric vehicle drives.

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